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ABSTRACT

The potential of the computer in helping foreign language students learn to use the grammatical principles of the target language for communicative purposes is discussed. A philosophical contrast between the terms of computer-assisted instruction (CAI) and computer-assisted language learning (CALL) precedes a discussion of current approaches to grammar, including pedagogical attitudes toward grammar in general, how current software represents those attitudes, and ongoing efforts to improve error analysis and feedback within that CAI paradigm. A psycholinguistic (rather than a linguistic) perspective is suggested as a different way of thinking about possible solutions to theoretical and pedagogical problems. This notion is developed into a framework for the design of CALL grammar materials that address the problems of error analysis and feedback from this psycholinguistic perspective. Implications of the psycholinguistic approach for classroom practice and for related research in mediated second-language learning are discussed. (CB)

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A Psycholinguistic Perspective on Grammar and CALL

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Introduction

The purpose of this chapter is to discuss the potential of the computer in helping foreign language students learn to use the grammatical principles of the target language for communicative purposes. There is considerable disagreement in the field of foreign language education about whether grammar should be explicitly taught, because of the general feeling that learning grammar rules, or even learning to manipulate grammatical forms, does not contribute directly to learning to speak grammatically in spontaneous communication. This chapter suggests that a psycholinguistic rather than a linguistic notion of grammar is essential to the organization of such language learning, and will show how the computer is ideally—perhaps uniquely—suited to assist learners in that effort.

The argument necessarily involves theoretical considerations and exploration of general pedagogical concerns in order to establish a psycholinguistic perspective on grammar before ways to implement that perspective in computer materials can be suggested. The first part of the chapter will briefly propose a philosophical contrast between the terms CAI (computer-assisted instruction) and CALL (computer-assisted language learning). The second part will deal with current approaches to grammar, discussing (a) pedagogical attitudes toward grammar in general, (b) how current software represents those attitudes, and (c) ongoing efforts

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to improve error analysis and feedback within that CAI paradigm. The third section introduces a different way of thinking about grammar, suggesting a psycholinguistic perspective as a possible solution to theoretical and pedagogical problems. The fourth section then develops this notion into a framework for the design of CALL materials for grammar, and addresses the problems of error analysis and feedback from this psycholinguistic perspective. The chapter will close with a brief discussion of the implications of this psycholinguistic approach for classroom practice and for related research in mediated second-language learning.

CAI and CALL

Early attempts at developing computer-assisted instruction in foreign languages were understandably constrained by limits on what the technology could do; to use the computer idiom, the earliest foreign language computer-assisted instruction (FL CAI) was *machine-driven.* Limits on the amount of machine memory, on the ability to produce foreign language accents and special characters, on flexibility in judging student responses, etc., all required that software developers stay within a narrow range of possible exercise types, most commonly vocabulary and drill-and-practice grammar lessons. In the early days, many of the lessons being marketed were developed not by teachers but by programmers who had only a superficial knowledge of the foreign language and little if any idea of language pedagogy. At that point, the general perception of the computer's role in language teaching (that it only provided expensive ways to undertake already commonplace activities) was similar to that of many new technological media: it has often been said that television entertainment began by doing in its flashy new way essentially the same kinds of shows as had been popular on radio.

More recently, the increasing sophistication and power of computer technology has reduced the extent to which machine limitations control the design of materials, so that pedagogical considerations have come to the fore. As a consequence, FL CAI is now *teacher-driven,* both practically and conceptually—practically because foreign language teachers are participating in the design and production of software, and conceptually because current developments in FL software are increasingly dominated by the notion that the computer should act as much as possible like a good teacher.

It is time for FL CAI to become *learner-driven.* The computer's full potential for interaction with the individual learner cannot be exploited until decisions about the kinds of materials to be used and their design are based on theoretically motivated and research-based insights into the language-*learning* process rather than on traditional precepts about the language-*teaching* process.

Increasing use of the acronym CALL instead of CAI seems to suggest that this change of perspective has already taken place, but the terms are not always contrasted to the same purpose. Underwood (8), for example, implies that the term CAI in a strict sense should refer to lessons that actually present new instruction (i.e., tutorials), and seems to consider drill and practice as CALL, although of the most prosaic kind (p. 38). Another possible distinction has CAI referring to computer activities that replicate and extend classroom explanations and drill on grammar and vocabulary, and CALL referring to software that engages students in using the target language (TL) for interesting purposes without focusing attention explicitly on the formal aspects of the language they produce.

In this chapter, the terms CAI and CALL are not used to represent different types of lessons, but rather to connote different orientations in foreign language education. An exploration of current language-education philosophy and experience suggests that what is conventionally *taught* under the label of grammar is not what students need to *learn* in order to communicate grammatically. In this chapter, CAI thus refers to the use of computer materials designed to extend the role of teacher and/or workbook, to present or drill grammar as it is thought of traditionally in materials organized according to analyses of the target language. CALL, on the other hand, refers to uses of the computer developed on the basis of hypotheses about the process by which learners come to be able to communicate grammatically in that language. *Computer-assisted instruction in grammar,* from this perspective, is one extension of applied linguistics, since that is the discipline that concerns itself (among other things) with the generalizations that describe the abstract system of a given language. In contrast, to promote *computer-assisted learning of grammatical processing,* it is necessary to conceive of foreign language education as applied *psycho*linguistics, which concerns itself (among other things) with the way the human mind uses language.

Helping the student to learn grammar from any perspective is not necessarily the most important role for the computer. There are computer activities that assist the learning of vocabulary and cultural material, and more and more foreign language software is appearing in which the second language is used for content learning, problem solving, and recreational purposes. Many are excellent programs (although many are not), and having a variety of computer activities is obviously important in helping students develop the wide range of capabilities that is crucial to communicative language use, as well as in holding their interest. One purpose of this chapter, however, is to suggest that the learning of psycholinguistic processing of grammar underlies and is more involved in the general effort of learning a TL than the learning of "grammar" in its current restricted sense. From this perspective, therefore, the development of CALL materials focusing on grammatical processing may be one of the most important concerns for FL education.

Grammar and Language Learning

Teaching Grammar vs. Learning to Speak

To talk of teaching a language is to imply that there is a body of information, a subject matter, that teachers know and transmit to students. For centuries foreign language education accepted without question that the subject matter to be taught is the language, a set of vocabulary items, and a set of grammar rules based on the description of the target language furnished by linguists. In this view, it was the teacher's responsibility to select, simplify, and order these rules and transmit them to the students; it was the learners' responsibility to "know" these rules and practice "using" them until they could be "applied" accurately in translating and parsing sentences.

In recent years, however, most teachers have come to agree that the goal of language education should be not the learning of "the language"—an intellectually mastered body of material—but rather the learning of "how to speak the language," that is, a complex skill. But a complex skill cannot in fact be taught the way a body of information can; teachers can describe and demonstrate the behavior that constitutes the skill, but memorizing or understanding that description is not the same as learning the skill itself. In short, "teachers" of a complex skill cannot really teach it; they can only assist the learning by providing learners with structured opportunities for practice.

Speaking a language is arguably the most complex skill human beings ever acquire, and so, appropriately, most good language teaching these days is designed precisely along the lines of assisting learning. Teachers use most of their class time to model the TL and provide students with authentic situations for interaction. Students must undertake to express their own ideas on the TL, developing their language skill primarily on the basis of feedback on the success of that interaction. Given a certain amount of motivation, intelligence, and goodwill, students typically learn a great deal of language with this kind of help.

But there is still one component of language thought to be a teachable subject matter, a body of information to be mastered, and that is the grammar of the TL. Grammar is conventionally presented in foreign language textbooks as a set of descriptions of the formal features of the target language codified as rules for its correct production. Nowadays students are not required to recite the rules, but they are still expected to be able to "use" them—not in order to translate and parse, but to give correct TL form to the expression of their own ideas. Grammar rules thus seem to constitute a body of information to be transmitted to students, and mastery is supposedly achieved through drill and practice, although it is,

ideally, demonstrated finally in spontaneous grammatical communication, not on discrete-point tests.

The problem is that although "the rules" of the language are taken for granted as defining grammaticality, the connection between *teaching grammar* and *learning to produce language grammatically* seems unreliable at best. Students and teachers alike feel that learning and/or practicing grammar rules is of little help in the effort to communicate one's own meaning accurately (let alone appropriately) in authentic spontaneous conversations. As a consequence, the grammar explanations in language textbooks have dwindled over the years, and methodology textbooks too have devoted less and less attention to training teachers to explain grammar. Nonetheless, most teachers still cannot help but feel that students must somehow be brought to some degree of demonstrable accuracy in the grammar of the TL through an understanding of how grammaticality is achieved. In a word, more or less reluctantly, teachers continue to teach *grammar,* hoping that students will learn *grammaticality.*

Grammar on the Computer

It is this complex of attitudes that has made many teachers feel that grammar work is exactly the right task to be relegated to the computer. Since the current philosophy of language teaching demands much heavier emphasis on the communication of meaning than on form, teachers feel that classroom time should be devoted as much as possible to authentic spontaneous interaction in the TL. Chastain (1), for example, says, "The goal of second-language educators should be to seek ways and means to expand the proportion of class time spent on the exchange of meaning in the second language" (p. 345). Of those teachers who favor the use of the computer at all, many feel that the machine can serve them best by taking over the tedium of drilling the student in the mechanical manipulation of language form, which is what grammar connotes.

It should be noted that still other teachers feel that grammar drill in any medium is incompatible with a focus on communicative competence and should be avoided entirely. They argue that the power of the computer, like that of the teacher, should be devoted entirely to communicatively oriented exercises, simulated communicative situations, etc., and they regard drill lessons as less worthy of attention either by the student or the programmer. Conflicting convictions about the value of teaching grammar thus undermine the effort in the classroom and on the computer. The result is a vicious circle: this grudging and negative attitude toward grammar inevitably prevents the development of innovative and exciting grammar software, and the fact that most computer grammar lessons have been mechanical and organized around discrete points of grammar

increases teachers' sense that even on the computer grammar is boring or pointless.

Nonetheless, grammar has been the focus of a fairly high proportion of the foreign language software developed so far. In the "machine-driven" stage of CAI, grammar lessons were considered second only to vocabulary drills in ease of programming because the surface grammaticality of student input on discrete-point items can be checked by a mechanical comparison of letters or words to the correct TL version. In the "teacher-driven" stage, grammar software is popular not only because it relieves teachers of a burdensome task but also because the computer imposes no radical change in the way the chore is handled and therefore poses them no threat. Classroom explanations of grammar often add little to the textbook presentation, which can thus be presented just as effectively on a screen. And computers, like workbooks, provide answers by which students can correct their own work, so using the computer for this purpose does not change the overall approach. For the most part, grammar lessons on the computer have been developed along exactly the same lines as grammar lessons in any other medium and, in effect, many of them are simply the same lessons "computerized" with varying degrees of attention to "user friendliness." Programs have focused on the same "subject matter to be transmitted" and have been flawed by the same uncertainty about whether, or how, learning grammar fits into learning to communicate grammatically. The one real advantage in doing grammar on the computer rather than in a workbook (as most grammar software is now designed) is that the computer can give students immediate feedback on the correctness of their input.

Feedback and Error Analysis in CAI

But even in the task of "teaching grammar" (i.e., promoting student mastery of a body of rules) current software is not notably successful except perhaps with very able students. Most students learn no more from grammar on the computer than they do from grammar in the workbooks, because much of the commercially available offerings are of the "wrong, try again" model, which only indicates *whether* student-produced bits of language match the TL model stored in computer memory (sometimes also showing the correct answer) without indicating *how* or *why* the student input does not match. The ability to provide immediate and supposedly helpful feedback on student FL production has always been claimed as a major advantage for CAI, although the reasons offered are sometimes given in behaviorist terms (feedback gives positive/negative reinforcement) and sometimes in a cognitive framework (feedback provides confirmation/disconfirmation in hypothesis testing). Current efforts to improve grammar software therefore tend to focus on different

ways of giving students better feedback, which is often said to be based on "error analysis."

One technique offers a feedback message that is in fact not based on analysis of the student's error at all, but presents an analysis of the *correct* answer; no matter what wrong answer the student types in, the feedback message is the same, explaining what it should have been. Teachers tend to feel that this restricted feedback severely constrains the usefulness of computer grammar lessons because students cannot always analyze how the "rule" they were using to produce their incorrect response differs from the correct one merely on being told "wrong," or even on seeing the correct answer after one or more unsuccessful attempts. Only in the most mechanical of drills, such as those that require students to choose among forms in the same paradigm, is this limited feedback message likely to be sufficient. Furthermore, students who have made only typing or spelling errors may resent grammar explanations.

In another technique, the computer indicates which specific letters of the student response do not match the correct answer. DASHER, for example, replaces incorrect letters with dashes, while TUTOR (the language of the mainframe PLATO system) and TUTOR-like languages for the microcomputer such as EnBASIC, TenCORE, and TEL, put symbols indicating a variety of error messages beneath the student's response (see Figure 1). Again, no *analysis* of the error takes place; the *location* of the error is pinpointed on the basis of the computer's letter-by-letter comparison of the student's input with the machine-stored correct version. This type of error markup has the advantage of allowing students to recognize their typing mistakes without having them labeled as grammar errors; the more detailed specification of the location and nature of the error (word missing, extra word, word belongs here, misspelling in ending, misspelling in root, etc.) can help the student to analyze the problem. But the machine looks only at the surface characteristics of the input; students must still derive for themselves the appropriate grammatical explanations for their errors, for example that the particular "misspelling" represents a wrong case choice as opposed to wrong gender.

A further level of feedback accuracy can be achieved if a CAI lesson author draws up a list of anticipated wrong answers for every item and programs the computer to give an appropriate message in response to whichever one the student enters. This technique allows the computer to give highly grammar-specific feedback if the author so desires. The disadvantages of this approach are that it is extremely time-consuming for the author to prepare and uses a great deal of machine memory; furthermore, unless the target student audience is relatively able and motivated, teachers will often find it difficult to anticipate all the wrong answers that may be produced. Similarly, they may find it even more difficult to establish unambiguous connections between certain wrong letters in the response and an appropriate explanation.

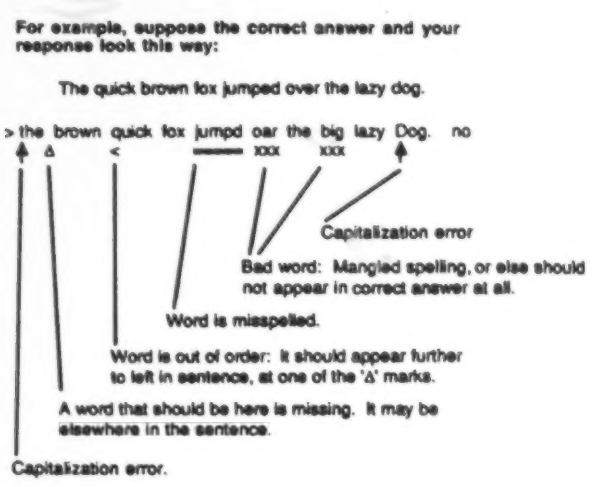
For example, suppose the correct answer and your response look this way:
The quick brown fox jumped over the lazy dog.
> the brown quick fox jumpd oar the big lazy Dog. no
Capitalization error
Bad word: Mangled spelling, or else should not appear in correct answer at all.
Word is misspelled.
Word is out of order: it should appear further to left in sentence, at one of the '∆' marks.
A word that should be here is missing. It may be elsewhere in the sentence.
Capitalization error.

Figure 1. Answer mark-up on the PLATO system

The most sophisticated technique for providing "intelligent" feedback to student errors is based on current efforts to develop machine parsing, by which the computer is programmed to do a linguistic analysis of the student's response, comparing it to a stored analysis of the relevant grammar rules of the TL and returning a feedback message based on that comparison. The lesson author does not need to specify anticipated wrong answers, because the program can identify them. The development of computer parsing is still in its infancy (see Chapter 8 by Underwood in this volume) and no commercially available foreign language software incorporates such feedback mechanisms, but some linguists working in the area of artificial intelligence believe that limited parsing techniques will be available before too long. If so, it will be possible for the machine to analyze student errors in terms of linguistic units such as roots and endings, to check for concordance between adjectives and nouns or subjects and verbs, for example, and to give feedback in terms of grammatical categories and rules.

All these efforts to enable the computer to inform the student with greater precision of the particular grammatical rules being violated by an erroneous response will certainly constitute an improvement in the instructional component of CAI vis à vis grammar. But such refinements do not address the issue of whether grammar should be explicitly taught at all (cf. Krashen, 6, ch. IV), because they do not concern themselves with the question of how the learning of linguistic rules (cognitive mastery of a body of material) can be made to contribute to learning how to speak a language or how to communicate in spontaneous interaction (development of a complex skill).

The question of whether to use the computer to help students learn grammar, and of how that might be done, cannot be separated from this larger issue. The following section will suggest that a different perspective on grammar might provide a better basis for understanding how it functions in communication.

Psycholinguistic Processing

Linguistic vs. Psycholinguistic Rules

A Psycholinguistic Notion of Grammar. How do "grammar" rules function in the act of speaking and comprehending language? Speakers do not begin with grammar rules and proceed from them to construct an utterance: they begin rather with an idea to communicate. To express one's own meaning is to *encode* it in grammatical and appropriate linguistic form; to understand someone else's utterance is to *decode* its form so as to arrive at the meaning. Speakers of a language must follow the same rules for encoding and decoding if their ideas are to be mutually comprehensible. To learn how to speak and understand a second language is therefore to learn how to do that encoding and decoding by the rules of its speakers rather than the rules of one's own native language community. *But the rules "used" by speakers for encoding or decoding meaning are not the rules common to foreign language textbooks.* The linguistic rules describe how the grammatical utterances of a language are related in its abstract system, and they describe the constraints on the surface form of an utterance, thus dictating its final form, but they do not describe the psycholinguistic process by which a speaker constructs the utterance.

The formulation of such a description, of the processing rules of a language (i.e., the rules by which its speakers process meaning into form and vice versa) is one of the goals of the field of psycholinguistics. The domain of psycholinguistics may overlap in some areas with the domain of psychology, but there are many psychological dimensions to language learning that cannot usefully be called *psycholinguistic.* Individual learners bring to the task complex and different sets of psychological characteristics that influence language learning in ways psycholinguists are only beginning to explore. For example, psychological factors such as motivation, cognitive style, and preferences for perceptual mode all influence the student's approach to second-language learning (and may influence individual students' ability to profit from using the computer), but there is as yet no clear evidence that these factors have a variable influence on how the learner structures language psycholinguistically. That is to say, there is no reason to believe that integrative motivation or field-independant cognitive style, for example, have a direct effect on learners' ability to use subordinate clauses or the dative case to encode meaning.

The interaction of these various individual characteristics with the process of language learning is not yet clearly understood, but it seems more useful to regard them as variables that affect the way the learner's mind comes to grips with the *general* task of language learning, long before the actual processing of meaning comes into play.

The following sections will explore the implications of a psycholinguistic notion of grammar with regard to the way grammar might be learned. These implications must be made explicit before the computer implementation of this perspective can be suggested.

The Processing of Meaning. In principle, a grammar in the psycholinguistic sense includes specifications for the relationships between the meanings human beings might want to express in language and the forms agreed upon by a given language community to express those meanings. Ideally, then, one would want a foreign language textbook to give learners a description of the native speakers' processing rules, starting with some prelinguistic specification of (1) a meaning to be conveyed, proceeding step-by-step through (2) the encoding operations, and ending with a specification of (3) the surface linguistic form. (The comprehension model would describe the reverse.) Unfortunately, this psycholinguistic processing happens so automatically and so fast in one's native language that introspection into the act is virtually impossible, and psycholinguists are far from able to supply sets of processing rules as linguists have supplied system rules. But it is not impossible to construct a simplified model of how a language conveys meaning—and, in fact, fluent educated nonnative speakers, such as language teachers, may be best able to make such an analysis.

None of the three components in the processing can be taken for granted. It is often assumed that the *kinds* of meaning (the first component) human beings want to express are universal (although the content words for a topic like the theory of relativity are not), but that assumption overlooks the fact that of the infinite number of bits of meaning available for expression, each particular language has a different subset of concepts that must be marked *grammatically* rather than by choice of vocabulary. To speak a language, one must "know" which bits these are, although for native speakers and naturalistic learners this knowledge is not conscious or explicit. This point is seldom made with any generality in textbooks, despite the fact that certain forms such as grammatical gender are presented on this basis. It is crucial that language learners understand that not only the kinds of grammatical marking but also the concepts they mark vary from one language to another. For example, the *shape* of an object is not a bit of meaning that must be grammatically indicated in English (it can be implied by the name of an object, as in "sphere," or by an adjective such as "round") but in Navajo a verb of handling must be given a grammatical marker to indicate the shape of its direct object. In some languages the *purposefulness* of an action must be marked on a verb; in

some languages nouns must be marked for their position on a scale of *animacy*, and so on.

The second component of processing is the set of coding systems that handle the marking of meaning. Human languages have a small number of systems: (1) function words, (2) ways of changing lexical form such as prefixes, suffixes, infixes, vowel changes, etc., (3) word order, and (4) suprasegmental features such as stress and tone. Each language uses some subset of these systems, and different languages may use different coding properties to convey the same bit of meaning. For example, location may be indicated by a preposition or function word in one language, but by a noun suffix in another. Traditional grammar explanations give such scanty attention to this important component of processing that students often have no idea of the differences in kinds of meaning conveyed by verb endings and noun phrase endings (regardless of whether textbooks use technical grammatical terminology or not).

Speakers must also know how to choose the right form from the paradigm of that coding system for a particular context. For example, a German speaker needs to "know" that endings on noun modifiers mark case relations and that it is the accusative case that marks transitivity. Further, the speaker needs to "know" that there are different accusative forms marking the three grammatical genders and yet another marking plurality. Traditional grammar presentations, however, tend to present only the latter part of the processing.

It is important to note, on the other hand, that not all of the bits of code in a language are directly related to a specific bit of meaning. Some forms may once have had meaning that has since been eroded in historical changes. Moreover, some forms may carry information that is also, and more clearly, represented elsewhere. For example, personal endings on verbs are said to indicate which noun is the subject, but in languages like English and German, which require a sentence to have an explicit subject, the verb ending is actually redundant, because nominative case forms or the position of a noun phrase indicate the subject much more clearly. In Russian or Spanish, in contrast, the subject is often omitted and the verb ending is correspondingly more important. In another example, although the dative case on sentence objects in German often carries the meaning "recipient," the dative case on objects of the prepositions *aus, bei, mit,* and several others carries no discernible meaning. Those prepositions always take the dative, that's all, just as some others always take the accusative. When learners get the case wrong after these prepositions, the error causes no confusion about meaning, but the sentence is ungrammatical. Some of the formal requirements in a language, therefore, cannot be explained in terms of meaning but can only be stated as arbitrary surface structure constraints, as Higgs (5) points out in his hierarchy of explainability.

The term "meaning" usually refers to semantic information. But many grammatical structures encode syntactic information, clues about the organization of the utterance. For example, a relative pronoun encodes the syntactic information that a separate sentence has been embedded to modify one of the main sentence's nouns. Several semantic categories may be merged into a single syntactic one: the semantic roles of both agent (as in "I warm the coffee") and experiencer (as in "I am cold") are represented by the syntactic subject in English. These combinations too may differ across languages; in German, for example, the experiencer is not rendered in the nominative case as the agent is, but in the dative case as the recipient is.

This psycholinguistic perspective on what grammar is and how it operates in the mind of a speaker provides a basis for understanding why the learning of traditional or linguistic grammar has not been of much use to students. Because textbook explanations of grammar are based on linguistic rules, they describe the required final form of an utterance, focusing almost exclusively on the third component of the three discussed above, the required surface form, rather than on the psycholinguistic process that leads to it. Most textbook grammar rules "explain" a structure in terms of its relationship to other structures in the system as a whole (for example, the passive is usually explained in terms of its structural relationship to the active, and the negative and interrogative in terms of the positive and declarative). In other cases, structures may be explained by reference to other elements in the sentence. ("If a clause begins with one of this list of conjunctions, the finite verb must come last.") Most rules describing grammatical structures make only indirect reference to the meaning they encode, and even then this meaning is often given in terms of grammatical labels. These labels are supposed to be familiar to students who have studied English grammar, and the assumption is that the labels remind them of the way meaning is processed in English. So, for example, "explaining" that the dative case in German is used for the indirect object is supposed to evoke in students the knowledge that that term refers to the recipient of an action so that they will use the dative case in German to encode that notion. The vast majority of grammar points in most foreign language textbooks receive only such surface-based explanations.

There are, of course, structures that can only be explained in terms of the distinctions in meaning they convey, where the explanation ties to function like a processing rule. For example, in prepositional phrases of place in German that use one of nine prepositions, the dative case specifies the meaning "place where" and the accusative "place to which." But even though textbooks explain that the concept of directionality is the crucial determiner of case, students are routinely diverted from the concept by being told that the presence of a verb of motion is the easy clue to the need for the accusative—which will lead them to make errors in sentences like "We drove around in the city for two hours" (dative) or "The teacher

wrote the grades in his notebook" (accusative). Still worse, explanations for many structures are short-circuited when the meaning is defined in terms of traditional grammatical labels, which are often misleading or outright wrong: the difference between the imperfect and the present perfect is routinely labeled as one of tense, but it is in fact a difference of aspect, a term that almost never appears in French or German textbooks.

Can Psycholinguistic Processing Be "Taught"? Even if speakers do use psycholinguistic or processing rules rather than linguistic ones in constructing or comprehending utterances, that is not of itself an argument for teaching processing rules to language learners. Knowing what the processing rules of a language are is still not the same thing as being able to use them. Students will not learn to speak solely on the basis of cognitive mastery of processing rules (via CALL or otherwise) any more than they do solely on the basis of mastery of linguistic rules. In learning any complex skill, understanding why and how the behaviors work is only one way of organizing the learning, making it more efficient, reducing confusion and misdirected hypothesis testing. The skill itself can only be developed as the learner practices it. Explanations of processing rules will be of use to classroom learners only if they are thought of as organizing principles to assist ongoing active efforts to communicate in the target language. The understanding and the doing must be connected; teaching students to understand linguistic rules has not assisted the doing, because the rules do not describe how processing is done.

The argument advanced here is thus twofold. (1) If students are to be given any explicit explanations of grammar, an understanding of processing rules will serve them better in learning to communicate in a new language than will a knowledge of linguistic rules. (2) Beyond elementary school levels classroom learners need some organizing principles for their learning. The first assertion is based on the examination of the function of both kinds of rules in the preceding sections of this chapter. The second is a topic of serious disagreement among foreign language teachers, some of whom are convinced that classroom learners need only to be psychologically receptive to large amounts of comprehensible input without any explicit discussion of grammar (cf. Krashen, 6, ch. III).

The theoretical backgrounds for these opposing positions need not be rehashed here; the point is that the claim forms a testable hypothesis (and the computer provides an appropriate medium for testing it, as is suggested at the conclusion of this chapter). Research studies could compare the communicative skills of three groups of students, all in communicatively oriented classrooms: (1) those who receive no explanations of grammar at all, (2) those who receive traditional grammar explanations like those common to communicatively oriented textbooks, and (3) those who receive explanations of processing. The research instru-

ment might be the ACTFL/ETS Oral Proficiency Interview or any reliable and valid test of communicative abilities. Such research cannot be undertaken, however, until the processing approach has been implemented. (For a more detailed discussion of the theoretical basis for conceiving of grammar in psycholinguistic terms and of the pedagogical implications of this approach, see Garret, 4.)

Why Implement the Processing Approach via CALL

This discussion of the differences between the traditional approach to grammar and the psycholinguistic perspective should not be taken to imply that the latter represents a total change from current practice. Many teachers intuitively use a psycholinguistic perspective to elaborate on textbook rules so as to help students use structures accurately in spontaneous speech. (Perhaps the ability to do this is one of the characteristics that makes a good teacher.) But teachers have not been trained from this perspective, and most feel that they should not spend much class time discussing grammar. Although the desirability of using class time for personal and group interaction and spontaneous communication is unarguable, the corollary is the need to provide students outside of class with access to the processing principles that will help them organize their learning and the means to practice them efficiently and individually in the absence of a teacher or tutor.

The computer has advantages, including its ability to individualize instruction. It is the ideal medium both for helping students understand the psycholinguistic perspective on language and for helping them to use it to develop their own processing in the TL.

Individualization is claimed to be one of the major advantages of CAI, but so far individualized instruction has meant little except allowing students to control some of the conditions under which they proceed through the material. Pace is controlled by the learner in virtually all lessons except in game formats, and even there the learner can usually choose among several pace settings. In other attempts at individualization, some CAI lessons allow students to choose whether they want audio, or in which order they enter lessons, or whether to review missed items. All these options accomplish a certain amount of psychological individualization in allowing students to impose their learning-style preferences on the lesson, but the *material* being taught is still the same for all students, and it is being taught in the same *way*.

There is much more to individualization than student control over superficial details of an instructional presentation. Individualizing learning assistance for psycholinguistic processing requires an assessment of the learner's unconscious language processing and the use of that assessment to design the learning needed. Yet it would be impossible for

classroom teachers to collect the detailed data needed to assess each student's processing of each grammatical structure. Even when teaching one-on-one, a teacher cannot store the student's every utterance and constantly analyze the patterns of errors, combined with the patterns of correct use, needed to hypothesize the individual's idiosyncratic interlanguage rule for "when this form is used." Interlanguage research has shown that even learners with the same native language and the same amount and kind of input in the target language may still develop very different interlanguage rules for any given structure, so the teacher cannot assume that one kind of idiosyncratic processing will be common to all students in the class (Garrett, 3). Since neither methodology nor foreign language textbooks have as yet adopted the notion of processing as an organizing principle, teachers have no training in applying this approach to their analyses and no support for it in their materials.

The computer, on the other hand, can be programmed not only to present instructional material but also to elicit student response to it, collect information about student performance, analyze that information for evidence of idiosyncratic processing, and give feedback based on that analysis to the learners. Finally, the computer can, if teachers desire, use the analysis to control the choice of the next instructional material offered to help the learner reshape the processing. Used in this way, CALL offers major advantages to students over CAI. At the same time, this kind of CALL fills another frequent demand, that the computer be used to do things that cannot be done otherwise, rather than provide an expensive electronic version of other media.

How to Implement the Processing Approach via CALL

Having explored the reasons foreign language education should conceive of grammar in psycholinguistic rather than in linguistic terms and why this approach should be implemented on the computer, this section will suggest a framework for designing CALL activities that will help students use this perspective on grammar in organizing their own language learning.

Topics for CALL grammar lessons can be roughly divided into four groups, which will be discussed separately below: (1) consciousness raising, (2) major grammatical topics in the TL, (3) particular structures, and (4) the surface structure. It should be clearly understood at the outset, however, that the order in which they are discussed herein does not represent some absolute order of presentation to the student; these do not constitute a syllabus, but are conceptual groupings. The best order of lessons or topics from among these groups needs to be determined empirically according to pedagogical principles and to the nature of the TL.

Consciousness Raising

The first topic, a general prerequisite to helping the learner understand and make use of the processing approach, could be called consciousness raising. Students must be brought to think about language and about language learning in terms of the acquisition of processing. They will almost certainly never have thought about "how language works" in any terms other than traditional grammar labels, and they generally approach the task of learning a second language with a very negative attitude toward "grammar" as they have always conceived it.

Consciousness-raising lessons should lead students to understand the concept of processing itself and the variety of ways in which any language's forms encode a variety of different kinds of information—semantic, syntactic, pragmatic, discourse, and sociolinguistic. The purpose of these lessons is not to teach the terminology for discussing all this, but to give students a way of thinking about processing that will help when they come to processing problems in the TL. The material should take the form of highly interactive tutorials with many examples in the native language—but "highly interactive" should not be allowed to mean only that students often press NEXT or ENTER. (Many lessons called tutorials are nothing more than page-turning exercises.) Students' attention must be engaged constantly; after the presentation of any concept or set of examples they can be asked for their intuitions or asked to respond so as to show that they have understood the material. Once they have developed some insight into the bits of meaning that must be grammatically encoded in English, the general concept of processing can be extended to show that other languages require grammatical marking for quite other bits of meaning. A wide variety of examples in other languages, translated literally, usually intrigues students. Even those who resent "the language requirement" and feel no motivation to learn a foreign language can be fascinated by insights into "how language works."

Another set of consciousness-raising CALL tutorials can help students establish a framework for understanding certain major grammatical concepts. It cannot be assumed that even those students who have "learned English grammar" have any conceptual grasp of what the labels, categories of analysis, and explanations actually mean in terms of expressing one's own thought in language. Among the most important topics might be:

- What does grammatical case mean? What are the differences between a language that marks case with word order and one that uses inflections? What is the relationship between semantic roles, such as agent, patient, recipient, and grammatical notions such as subject, direct object, indirect object?
- What is the difference between tense and aspect? How do the concepts interact in verb expressions?
- What is the difference between main or coordinate clauses and sub-

ordinate ones? Why do languages have subordinate clauses?

- What is the difference between finite and nonfinite verb forms? What are the various nonfinite forms used for?
- Which grammatical structures operate mostly on a sentence level, and which are used to organize meaning in larger units, such as paragraphs or conversations?

Major Grammatical Topics in the TL

A second category of CALL lessons is needed to organize the major grammatical topics of the TL. A few lessons giving a general overview might be introduced at the beginning of the language course, but it will be more important to establish a piece of the conceptual framework at each point in the syllabus when a new kind of TL structure is introduced. (For example, the first time a verb tense is explicitly presented, a general discussion of the TL tense system is appropriate, and so on.) The number, scope, and nature of the major organizing topics will of course vary from one language to another. Here again, multiple examples are vital, but it will probably be more efficient to limit them to the native and the target language, so as to provide a contrastive analysis of processing. (Most of the examples that have made their way into textbooks are based on contrastive analysis of *linguistic* rules, not on contrastive processing.)

Even at these first two levels of CALL materials, the lessons can be individualized. Some students have an intuitive understanding of psycholinguistic processing, without having thought about it in those terms, or can grasp the explanations very quickly and may need only a little help to make their understanding conscious and generalizable. Others may have a thorough grounding in the terminology and the surface structures to which it refers but little grasp of communicative uses. Still others will have neither. These tutorials on grammar should include a fairly small set of questions after an introduction of the topic to allow students who do understand it to bypass unnecessary explanations or exercises and proceed to more relevant sections. Those who find later that they have not grasped the material well enough can always return to it; students can be encouraged to go back to these general lessons whenever they find themselves confused about the way a particular structure fits into the processing system of the TL.

Particular Structures of the TL

The third and most complex group of CALL lessons must address the processing of particular grammatical structures in the TL. It cannot be taken for granted that reference to apparently analogous structures in English will be helpful. Contrastive analysis of *structures* will not necessarily pro-

vide clues to contrasts in *processing*. The discussion of how similar meaning is processed in English may be helpful, but lesson designers must be on their guard against assuming that a structure encodes the same meaning in two languages just because the grammatical label for the structure is the same (the subjunctive encodes a quite different meaning in French than in German).

Lessons on particular structures must allow students to focus separately on three parts of the learning: (1) understanding the concept to be marked, (2) knowing the form of the marking, and (3) developing fluency and semiautomaticity in connecting them.

The first part of this type of CALL lesson establishes the conceptual groundwork of the structure. Students practice recognizing those bits of meaning that dictate the need for the structure in question in contrast to those that do not. For example, when the accusative case is being introduced, students need help in distinguishing direct objects from predicate nominatives or other objectlike noun phrases that come after verbs (such as "I'm going home"), because in English it is word order that encodes direct-objecthood and so they may think that any noun phrase after the verb is a direct object. Students should practice on a wide variety of English sentences, indicating whether they contain a direct object, until they demonstrate a reliable sense of transitivity, whether it is labeled as such or not. (If after they respond to the English sentence the TL translation is provided automatically, with the relevant form highlighted, they will receive extra input.) If the TL notion of transitivity (or whatever) differs significantly from English, the next step is to offer a selection of TL sentences, again with the relevant form highlighted, showing the contrast and explaining it; these can also be followed by literal translation to point up the contrast. Curtin's (2) lesson on aspect in Russian is an excellent example of this kind of exercise, as is Shinall's (7) presentation of the perfect/imperfect difference in French.

In the early part of tutorials of this type, the meaning should be unambiguous and easy for students to recognize, but in time it will be especially important to offer as examples sentences in which the distinguishing features are less clear—in order to fine-tune their grasp of the concept. For example, in presenting those nine prepositions in German mentioned above following which the choice of case marks "place where" or "place to which," it is the *apparently* anomalous sentences that most clearly point up the fact that the case choice marks the concept of directionality, whether the verb expresses it explicitly or not.

The second part of the tutorial focuses on the purely formal character of the structure, the other end of the meaning–form continuum. Drills are set up so that no conceptual decisions are required; students know what category of form they need (i.e., which paradigm they are working from), and the point of the exercise is to practice using the correct bit of the paradigm in given sentence environments. (This kind of drill makes up the bulk of

traditional grammar lessons both in workbooks and in software.)

While the processing perspective makes it clear why drilling form alone will not help students to use a structure, even learning to make conceptual distinctions in additional CALL exercises will not of itself solve the problem, because the explicit focus of both conceptual and formal exercises is entirely different from the communicative situation. In spontaneous communication, a speaker's mind is not focused explicitly either on analyzed bit of meaning or on form. In virtually all conventional grammar exercises and tests, either the pattern of blanks to be filled or the drill instructions make the student aware of the particular "rule" that is supposed to apply, the particular structure being called for. Students' ability to perform well on such a test is no guarantee whatsoever that they will be able to produce the structure in communicative situations, where no such indication is provided. Students must therefore be given practice in bridging the gap between language-producing situations that make too explicitly focused a demand (drills on either meaning or form) and situations in which the demand is entirely unfocused (spontaneous communication). Only "open" (rather than discrete-point) exercises offer this opportunity—and it is in these CALL lessons that the transition is made between learning the components of processing and learning to do it.

Open exercises are ones in which the student's attention is not directed to one particular structure, either its meaning or its form. One type of open exercise is translation from English into the target language. Translation exercises have been out of favor for many years because teachers fear that they encourage students to attempt word-for-word renditions of the native language sentence. Although this might tend to be true in the context of the conventional approach to grammar, in which explanations are routinely given in terms of surface equivalences, under the processing approach it is much easier to train students not to translate word for word but to think about the different kinds of meaning in a sentence and work out the parallel processing required to render them in the TL.

In designing CALL translation exercises it is important to prevent students from making many extraneous errors, such as typos and misspellings or the choice of an unanticipated vocabulary item, since computer response to them can distract attention from the particular problem that needs work, and can be discouraging as well. One partial solution, which helps prevent extraneous errors but still avoids focusing conscious attention on a particular structure, is to supply with each sentence the vocabulary needed and other information appropriate to the task—gender of nouns, verb class, tense required, etc.—whatever information does *not* contribute directly to the production of the structure in question. This information can be given at the bottom of the screen for each sentence.

The same effect can be obtained with the "scrambled and dehydrated

sentence" format, in which the student is given a series of words or phrases in the TL and told to combine them to make a sentence. If the concept to be practiced is word order, then after the student has indicated the correct order of words or phrases the computer can automatically insert the necessary function words and inflections. If the exercise requires the student to supply inflections, the computer can take care of the word order on its own. At an advanced level the student might be given only a series of nouns and a verb and instructed to add any necessary function words and inflections.

These open exercises need not be used extensively for every structure to be learned, but they must occur regularly to prevent the gap between the students' ability to produce a certain form when they know it is required and their ability to realize unconsciously (or rapidly enough to seem so) when that form is required for the thought they want to express.

Checking Surface Structure

So far this chapter's suggestions for designing CALL lessons to help students understand processing and learn how to do it in a foreign language have dealt only with the connection between meaning and form. However, there are grammatical structures in every language for which some particular uses cannot be "explained" in terms of the meaning they convey; certain forms must be used in an utterance just because it would otherwise be considered ungrammatical. In other words, descriptive grammar rules impose a set of final constraints on utterances. The fourth level of grammatical processing, therefore, is checking the surface structure of what one is about to say against the template of grammaticality provided by the linguistic rules. Native speakers do not consciously use explicit normative grammatical rules to monitor production, except in deliberate attempts to speak "correctly" (as for example by remembering to use "whom," or not to split infinitives); usually this monitoring is entirely intuitive. But it is common for native speakers as well as second-language learners to self-correct, to back up in an utterance and repair it because of the feeling "it's going to come out wrong."

It has been argued here that linguistic rules do not themselves function as processing rules because generalizations about the nature of the product do not necessarily describe the process. Nonetheless, the end result of the psycholinguistic processing (the utterance itself) must be describable by the rules of the linguistic system in order to be grammatical, and it is in this way that psycholinguistic and linguistic rules intersect.

The ability to monitor successfully, in this psycholinguistic sense, depends on having an underlying set of intuitions about whether an utterance is grammatical, i.e., having the relevant competence in the Chomskyan sense. (It is not a matter of having a conscious knowledge of the relevant learned rule.) It is these intuitions that provide the template

against which to check the outcome of the processing; for the native or near-native speaker, the intuitions are established through years of interactions with a stable speech community whose norms are unconsciously analyzed and followed to ensure membership. Students, however, have fragmentary and unreliable intuitions about the TL (or about their own interlanguage version of it), and so they have inadequate templates for monitoring surface structure. It is sometimes said that the goal of language learning is to develop a competence as similar as possible to that of the native speaker, i.e., the same intuitions. Part of the task of language learning, then, is to build something like the native speaker's template, and that is accomplished by letting students submit their output to a model of the native speaker's template and helping them to understand how that template operates, so as to promote the building of their own.

CALL exercises on formally required surface structures are essentially no different form the form-focused exercises described in the discussion of the processing of grammatical structures where a meaning-form connection does need to be made. It is helpful to students, however, to be made aware that though the exercises are similar the processing is different.

Feedback and Error Analysis in CALL

Feedback in conventional grammar CAI is designed, ideally, to make students aware of the mismatch between their input and the required form in terms of linguistic rules. But even when students can correct a wrong answer after getting the standard "wrong—try again" feedback, their doing so does not guarantee that they understand anything about why they made the error in the first place, or why the "alternate" answer is the correct one, or what the error message (or even the exercise itself) is supposed to help them learn. Instead, they often revise their answers on the basis of a "binary correction strategy" ("If it isn't X, it must by Y.") Even when the TL paradigm for a structure includes three or four logically possible forms, students often adopt a rule of thumb for choosing between just two. For example, although in German there are four cases, students who make a case error in marking sentence objects and objects of prepositions usually correct it as if the choice were limited to dative and accusative. Though there are three genders, students confronted with a gender error often lump masculine and neuter together in contrast to the feminine. True, in many of the processing choices to be made, such a binary strategy does fit "the facts" of German: with few exceptions, if a verb isn't strong it's weak; if "nicht" is the wrong negative form it must be "kein"; if the article isn't definite it's indefinite; if the second-person pronoun isn't familiar it must be formal, and so on. (Other binary sets will obtain in other languages.) The issue for the teacher or CALL lesson designer who wants to supply appropriate feedback is not whether the binary correction

strategy invoked by students is inaccurate; knowing that it *is* invoked should make it clear that giving feedback that indicates an error and requiring that the error be corrected will not assure that students have been assisted in any learning at all.

Most of the feedback-design recommendations in discussions of computer-based instruction in any field are predicated on hypotheses from learning psychology—the advisability of "personalizing" the feedback with the student's name, or of varying it (or making it more palatable) by using responses like "fantastic/sorry" instead of "yes/no" or "right/wrong," etc. Discussions of feedback in FL software tend to focus on questions such as whether the response should be in the target language or not, whether students should automatically see (or should have the option of seeing) the correct answer and, if so, at what point in the sequence of correction attempts, whether hints should be given, whether students should be made to type the correct answer in, etc.

Unfortunately, none of these questions can be answered in the abstract or for the learner population as a whole. Some students prefer to figure out the right answer for themselves and will not accept the option of on-line helps even when they are offered and even when the responses they make indicate that they are far from understanding their own problems. They become disaffected or angry if the right answer is provided automatically, and learn little from it. Other students, in contrast, want to make minimal effort, and always choose to see the answer as soon as possible so as to be able to get to the next item, learning little from seeing it. Hints and selective response to errors (either surface responses such as the standard PLATO markup or DASHER's substitution of dashes for incorrect characters) may be helpful to students who know the material and only need practice in making their production more fluent, but markup or analysis may be perceived as frustrating or even mocking by students who don't understand their problems. These are important affective issues, and they must be taken into account in continuing attempts to individualize CALL. Nonetheless, they are only indirectly related to the issue of concern in this chapter, the learning of TL grammatical processing. The kind of CALL feedback required will vary according to the level of processing being addressed.

As was discussed above, current attempts to improve the feedback offered in conventional grammar CAI are based on the assumption that, to correct errors, the learner needs a reminder of the required final shape of the utterance, whether that reminder is an indication of which characters are wrong or a hint about the reasons one form or another is appropriate in terms of grammatical labels or the presence of other structures in the sentence. In some cases this assumption may be correct. If the error in question is simply a violation of a surface-structure constraint, resulting from the student's forgetting something that need not be understood but only memorized, or if the learner has grasped the concept but

has not had enough practice in choosing paradigmatic forms, then it is appropriate to supply such a reminder of the linguistic template.

When, however, the use of the grammatical structure in question is controlled by the presence of some kind of meaning, when the choice between the forms is dictated by conceptual considerations, then the feedback message should not assume that the error was made because of a formal problem; the student may not have understood or recognized the relevant meaning. For example, when students of German mark an indirect object with the accusative case instead of the dative, teachers commonly assume that the error is due to forgetting either the dative endings or the fact that indirect objects take the dative. In any particular instance, either of these may be the problem, but it is very often the case that students have no real sense of why the noun or pronoun is an indirect object; they have never been made aware that the *grammatical* notion "indirect object" is specifically constituted by the *semantic* relation of recipient. (The fact that many German textbooks also use the phrase "indirect object" to refer to any noun phrases in the dative, even those that represent the semantic role of experiencer, is not particularly helpful either.) Obviously if students have no underlying sense of what an indirect object is, a feedback message to the effect that they have forgotten what the dative endings are will be of no real assistance to their learning even if it does clue them in to the right answer. This circumstance is the basis for the prevalent belief that correcting errors does very little good.

How is one to know at which level of processing the student is going wrong? In sentences taken at random from students' TL production, it is virtually impossible to be certain; linguistic parsers, and error-analysis algorithms based on them, are becoming increasingly sophisticated in pinpointing the linguistic rules being violated, but they cannot determine whether the error was purely formal or was motivated by processing problems. The more spontaneous and authentic and communicative the utterance the more difficult the analysis. Even an observant and linguistically sensitive teacher listening to classroom interchanges cannot do more than develop hunches about why a particular student seems to be making particular errors, and students themselves are notoriously incapable of reliable introspection. It is possible to analyze students' TL data for patterns of errors and correct production, but a discouragingly large amount of data is needed to allow the postulation of idiosyncratic processing rules—far more, and far more complex, than can be generated by the conventional grammar exercises commonly assigned. The computer can play an important role in such research, as will be described briefly below.

It is clearly crucial to CALL that feedback address students' processing problems, but this does not pose an impossible demand on error-analysis programming. If the teaching of grammar is conceived in psycholinguistic terms from the beginning, then there will be no need for error-analysis techniques capable of analyzing all levels of processing simultaneously.

CALL exercises that focus student attention explicitly on one or another stage of processing—the conceptual distinctions to be marked, the interaction of one kind of meaning with another, the choice of grammatical structure, the choice of paradigmatic form, etc.—require that feedback address only that stage.

CALL lessons devoted to consciousness raising about psycholinguistic processing and to the exploration of major grammatical topics in the TL can ask for simple responses—yes/no, multiple choice—to check on understanding of the concept. In such lessons "incorrect" responses demonstrate lack of conceptual recognition, and the lesson should not respond as if the student should have known something but didn't. Rather it should show some understanding of why learners might have thought what they did, and explain how and why the processing of the language is different. Curtin's Russian aspect tutorial gives a one-sentence explanation as part of the feedback to both correct *and* incorrect responses in the exercises, whereas most drills that give any explanatory feedback do so only after a wrong answer. Curtin (personal communication) explains that she has found in drilling conceptually challenging material that students will sometimes deliberately give wrong answers in order to call forth explanatory feedback; giving it for correct responses as well helps the students by corroborating what might have been only a guess. Beginning this way helps to make students capable of more useful introspection into their own processing, and it also provides an explicit anchor for TL forms, which otherwise often float around in confusion.

The CALL exercises focusing on form then temporarily set aside considerations of meaning; in these, as has already been indicated, the feedback too can ignore the processing of meaning and can rest on the best available linguistic analysis, reminding students of the language system requirements.

In meaning-focused and form-focused CALL lessons, only one component of the processing of a given structure is dealt with at a time; each can thus be mastered before it is confused with the other. Then in later higher-order CALL exercises that demand that students process form and meaning together, it will seldom be difficult to ascertain whether an error is due to formal or conceptual problems. If students have been required to achieve consistently high performance on the purely formal drills, then errors on the open exercises can reasonably be assumed to be conceptual in origin. Even without referring back to earlier work, a CALL lesson can move back and forth between levels of processing to help students find the source of difficulty. Suppose that a student's score on an open exercise is unsatisfactory. The lesson can remind the student of the formal requirements, perhaps displaying the paradigm at the bottom of the screen, and can offer all the items again or present a new set of similar ones. If performance is then entirely accurate (or almost so) the student can be advised to work on learning the forms better. If, on the other hand, the

score improves only a little or not at all, then the program can suggest that the student may be having difficulties with the conceptual distinctions required and should review the earlier part of the lesson that dealt with them. If the exercise has a large enough selection of sentences, the lesson can continue to present unfamiliar items that require the same processing, so that students do not simply learn to produce the sentences they have learned how to correct.

In advanced-level open exercises where students construct sentences out of supplied elements, the program will have to be able to check the input against a stored list of several different correct sentences. The teacher/author is unlikely to be able to think up as many possible responses as the students, so rather than reject bizarre but grammatical answers the feedback might offer the stored list together with questions to help students decide whether their sentence is as good as the ones suggested.

If CALL exercises are designed to *diagnose* students' level of comprehension of a concept, or their mastery of a formal category, it may be appropriate to defer feedback until the end in order not to affect performance. Students should be told that the purpose of the exercise is to allow the computer to develop a basis for guiding them on the most efficient learning path. The diagnosis should then be given at the end, with a brief explanation of the criteria for the recommendation to review, proceed through the lesson, review a tutorial, or skip to another segment.

It is possible to design such diagnostic exercises to allow the computer to analyze students' errors for evidence of some particular processing problem. For example, since English-speaking students often have difficulty in recognizing indirect objects, one could put together a translation exercise containing indirect objects in a variety of sentence environments: in some of the English sentences it might be indicated with "to" (as in "I gave the money to my brother") and in others with word order ("I gave my brother the money"). If the program keeps tabs on the percentage of errors made on each of these two types of sentences, and if the percentage is significantly higher on the former type, then the program can provide a feedback message such as "You seem to have more trouble recognizing the indirect object when it has the preposition 'to' in front of it; remember it's the notion of recipient that counts—English can encode it two ways but German only with the dative case." It is up to the teacher-author to design these analyses on the basis of experience in understanding students' most common problems.

Integration of CALL and Classroom Activities

If adequate materials and an adequate number of computers were available, it would in principle be possible for teachers to assign explicit work

on grammar entirely to the computer so that they could, if they wished, devote all their class time to communicative and proficiency-oriented activities. It seems likely, however, that once the concept of processing is familiar, both teachers and students will feel more comfortable if the study of grammar is not entirely segregated. More important, the integration of CALL and classroom activities can be mutually supportive and result in more efficient learning. Processing exercises can be assigned as homework, following up on some classroom explanations or practice of new forms or functions, just as linguistic exercises always have been assigned. In addition, however, many of the CALL activities proposed here could be carried out *in preparation for* the classroom activities they relate to. The CALL work can serve as an advance organizer: a firm grasp of the relevant conceptual material should prepare students to understand much more of the near-native-speed language heard in class. Preparatory work of this kind can thus help turn much more of the input of the classroom into *intake*.

Summary

To sum up, then, the psycholinguistic perspective on grammar as processing suggests several different kinds of second-language learning tasks.

1). Learners must develop the ability to recognize the kinds of semantic and syntactic meaning that are obligatorily represented in grammatical form in the TL, and they must know what formal elements encode those meanings.

2). They must know the surface structure constraints of the TL well enough to be able to monitor the output of their processing so that it fits the TL linguistic template; that is, they must develop the intuitions about grammaticality that make up TL linguistic competence.

3). They must develop facility in actually carrying out TL processing, not just know how it works; they must learn a skill, not just master a body of material.

It has been argued in this chapter that CALL activities can be uniquely helpful (and may be essential) in organizing students' learning. CALL lessons can tailor the presentation of conceptual material to the level of understanding of individual students and allow each one the amount of practice he or she needs (1) to recognize the meanings that must receive grammatical form, (2) to master the required forms, and (3) to develop reasonable fluency in *using* that recognition and mastery in language production—in other words, students are individually assisted to learn the components of the complex skill of speaking the TL in preparation for doing so in spontaneous communication.

Many teachers intuitively use a psycholinguistic perspective on grammar to assist language learning in class. Most teachers, however, are neither trained nor inclined to think this way about grammar. No textbooks are yet written from this perspective or designed to offer teachers the necessary support for it, and FL textbook publishers are understandably reluctant, given the limited market, to invest in radically new approaches.

This means that those who are interested in developing CALL materials along the lines suggested in this chapter have a unique opportunity to effect a significant change in the way students learn a foreign language. Software development is enormously time-consuming, but for those experienced both in lesson design and programming it still takes less time than getting a new textbook written, printed, and into the hands of a significant number of teachers; moreover, software is inherently amenable to pilot-testing and revision.

The development of even limited programs to address the psycholinguistic processing of particularly problematic grammatical structures in a given language would allow empirical research on the claim that students will be able to make use of this kind of lesson better than conventional grammar teaching. But the research possibilities are not limited to studies of the efficacy of CALL. (Such evaluative studies cannot answer the general question "Do computers improve language learning?" but they can assess its usefulness to various kinds of learners, under various circumstances.) Computer-assisted *basic* research in classroom FL learning could be of enormous significance to the related fields of second-language acquisition and foreign language education. Studies using the diagnostic error-analysis techniques discussed above (and much more complex versions of them) could explore a host of important questions about how the classroom learner's processing resembles or differs from that of the native TL speaker and that of a naturalistic learner, questions with both pedagogical and theoretical implications. (See Garret [3] for a report on one such research project.) To pick a few at random: Are semantic concepts more likely to be transferred from the native language than syntactic ones? If structures are explained in processing terms, does that reduce the likelihood of transfer? Are there "natural" or "good" interlanguage rules (i.e., idiosyncratic ways of processing a meaning–form relationship) that are not the TL rules but do work as a step in the right direction, as opposed to unnatural or counterproductive ones? Is there a qualitative difference between the interlanguage rules or "good" language learners and "hopeless" ones? And if so, can the latter be explicitly helped to learn like the former? Are there universals in processing rules? Do students' processing rules always fit within a range of processing rules of natural languages, and if not how and why do they violate those universals?

The implications of such research can hardly be overestimated, and it

must be carried out by foreign language teachers. Most teachers, however, have never been able to undertake research because they cannot possibly make the time to collect and analyze data within their already overburdened teaching schedules. The computer makes it possible. A collaboration of teachers, CALL lesson designers, and programmers could develop the instrumentation to undertake second-language acquisition research hitherto undreamed of.

Until teachers and students try to bring the psycholinguistic perspective to bear, the hypothesis that doing so will make a difference cannot be tested, but theory, research, and common sense supply ample reason to believe that it will. In this effort the computer's role will be crucial.

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